BRH/DEP 71-8

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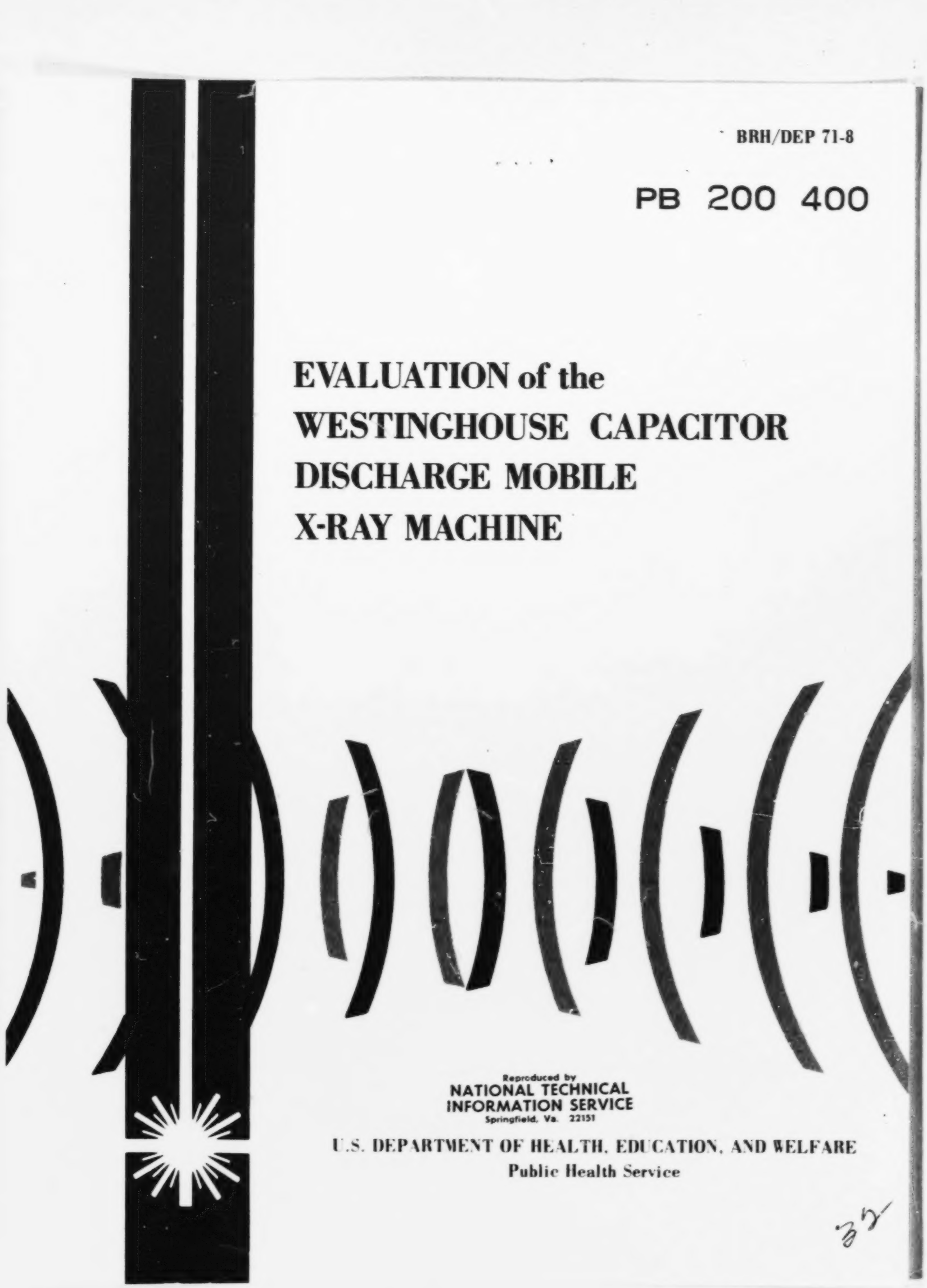
EVALUATION of the WESTINGHOUSE CAPACITOR DISCHARGE MOBILE X-RAY MACHINE



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EVALUATION of the WESTINGHOUSE CAPACITOR DISCHARGE MOBILE X-RAY MACHINE

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X-ray Exposure Control Laboratory
Division of Electronic Products

May 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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FOREWORD

The Bureau of Radiological Health continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in appropriate scientific journals and technical report and technical note series for the Bureau's divisions, offices, and laboratories.

The technical reports and notes of the Division of Electronic Products allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports and notes are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. They are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The Radiation Control for Health and Safety Act of 1968 authorizes the Secretary of Health, Education, and Welfare to establish an electronic product radiation control program which includes the development and administration of performance standards to control the emission of electronic product radiation. Performance standards are currently being developed for diagnostic x-ray equipment used by practitioners of the healing arts. To develop appropriate standards for new x-ray apparatus such as capacitor discharge equipment, typical operational data must first be obtained.

This report reflects the efforts of the Division of Electronic Products to keep informed of new and unusual types of commercial x-ray equipment and to gather information related to operating characteristics and radiation exposure in the use of such equipment. It presents the results of measurements made to determine the physical and operating characteristics of the Westinghouse model MO-120C capacitor discharge mobile x-ray machine. Although the results presented herein are considered accurate, they are not intended to certify that the Westinghouse machine complies with forthcoming performance standards, nor should the test methods used in this study be considered the official methods for determining compliance.

Robert L. Elder, Sc.D.
Director
Division of Electronic Products

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ABSTRACT

Tests were performed on a Westinghouse model MO-120C capacitor discharge mobile x-ray machine to determine accuracy of voltage indications, the relationship between voltage setting and current-time, line voltage effects and current drain, exposure reproducibility, focal spot size and location, correspondence between the collimator and light localizer, inherent filtration, half-value layer, radiation output, and tube housing and collimator leakage. Spurious radiation was found to originate in the tube under certain conditions. These conditions were investigated, and the observed radiation levels are reported.

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EVALUATION OF THE WESTINGHOUSE CAPACITOR DISCHARGE MOBILE X-RAY MACHINE

1. INTRODUCTION

Although the capacitor discharge principle of x-ray generation is not new, it has not been in general use in the United States until recently. Five manufacturers are currently producing mobile capacitor discharge machines for sale in the U.S., and their use is spreading. This report is the second of a series of Division of Electronic Products reports on the various makes available.

The capacitor discharge principle is employed in a mobile radiographic unit so that the machine can be operated from a normal low-current wall outlet, eliminating the need for special wiring at the various locations where use is intended. Such operation is possible because a charge sufficient to produce a reasonable x-ray exposure in a short time is stored in capacitors prior to exposure. The charge is accumulated over a much longer time period, eliminating the sudden surge during exposure required by conventional equipment.

Although the results reported herein are considered accurate, the test methods used in this study should not be considered to be the official methods for determining legal compliance with proposed performance standards for diagnostic x-ray equipment which will be issued under the Radiation Control for Health and Safety Act of 1968 at a later date.

2. DESCRIPTION OF MACHINE

The unit tested, a Westinghouse model MO-120C mobile capacitor discharge x-ray machine, serial number 34372, was rented directly from the manufacturer for the purpose of this evaluation. A photograph of the machine is shown in figure 1, and the manufacturer's specifications are listed in appendix A. The wheels are fitted with brakes which are released whenever the brake-release bar on the upper surface of the handle is pressed downward. The unit can be moved by one person. The tubehead can be oriented in any direction normally required, and the collimator can be rotated about the axis of the beam. Friction locks are available for all motions. The face plate of the collimator is 22 cm from the focal spot. The cassette box is located inside the cabinet and is lead shielded except on the side farthest from the x-ray tube. Plungers inside the control unit allow the capacitors to be shorted mechanically. The collimator has scales indicating the beam size at 100 and 150 cm.

The control panel and exposure switch are shown in figure 2. The kV and mAs are determined by the setting of the thumb wheel which is connected to a drum bearing a technique chart. The "technique" switch provides two techniques for each setting of the thumb wheel. In the "low" position, the mAs of a given exposure is about 30 percent of its starting kV. In the "high" position, the starting voltage is about 10 kV higher than in the "low" position, and the mAs is about 15 percent of the starting kV. If the thumb wheel is set so that in the "low" position the starting voltage is above 90 kV, the technique switch has no effect. The "charge" button initiates charging of the capacitors. After charging, the capacitor voltage decreases slowly by leakage through the bleeder resistors. When it has fallen about 2 kV, it is automatically recharged to the original level. The collimator contains a lead shutter which blocks the beam at all times except just before and during exposure. The power supply has a stabilizing transformer to allow use over a range of line voltages without adjustment. The "discharge" position on the power switch discharges the capacitors through the tube at a low current while the shutter blocks the resulting x-ray beam. The kV meter actually indicates twice the cathode voltage, and the light below it indicates the presence of a charge on the anode capacitor. A thermal switch on the tube housing prevents exposure when the housing is overheated.

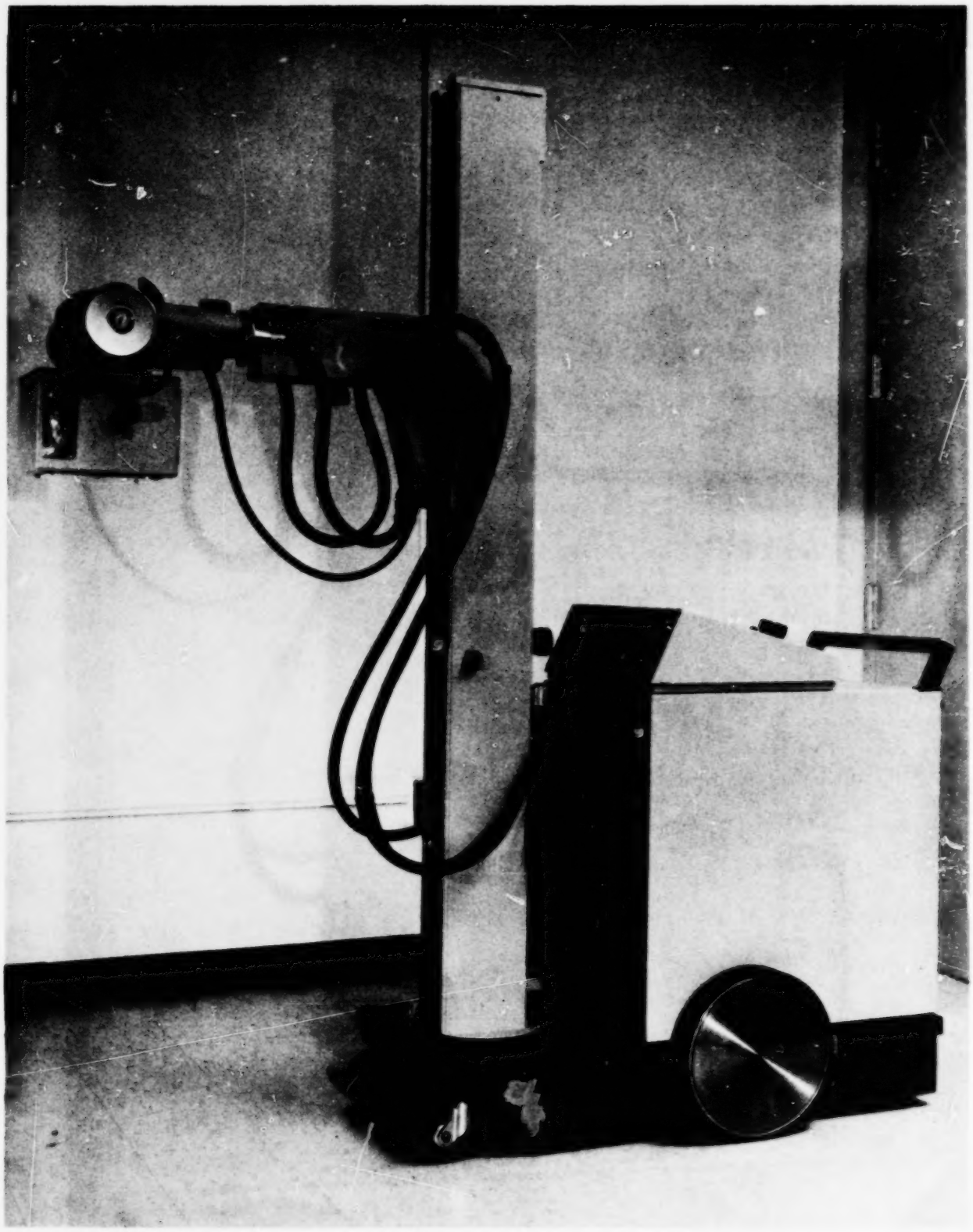

Figure 1. Westinghouse capacitor discharge mobile x-ray machine.

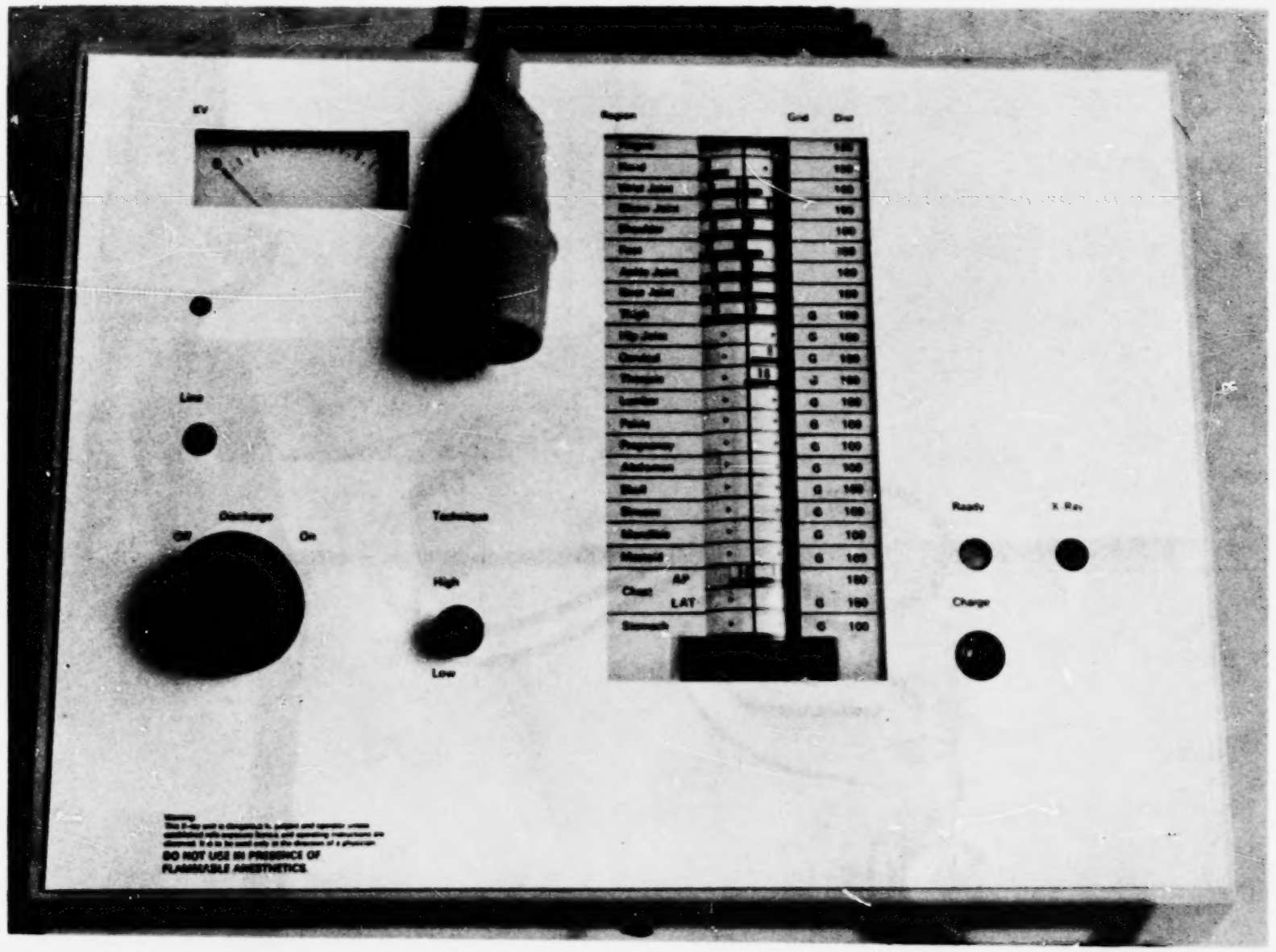

Figure 2. Control panel and exposure switch for Westinghouse machine.

A block diagram of the circuit is shown in figure 3. Solid lines indicate specific circuit connections, while dotted lines indicate information flow. When the charge button is pressed, the control circuits energize the high-voltage supply which charges the capacitors. The anode and the cathode each have capacitors to ground which are charged respectively to plus and minus one-half of the total voltage. When the preset voltage is reached, the kV-sensing circuit causes the high-voltage supply to be deenergized. The capacitor voltage appears across the tube at all times, but the tube is grid-controlled and normal tube conduction is suppressed by application of a negative bias on the grid. When an exposure is to be made, the exposure button is pressed to the first position which causes the tube filament to heat, the shutter to open, and the anode to rotate. After 1 second, if the button is pressed to its second position, the grid bias is removed and current through the tube causes the production of x rays. The kV-sensing circuit stops the exposure by reapplying the grid bias after the capacitors have discharged to a voltage predetermined by the kV setting. The capacitors, which have a combined value of 1.0μF, discharge 1 kV for each mAs of exposure.

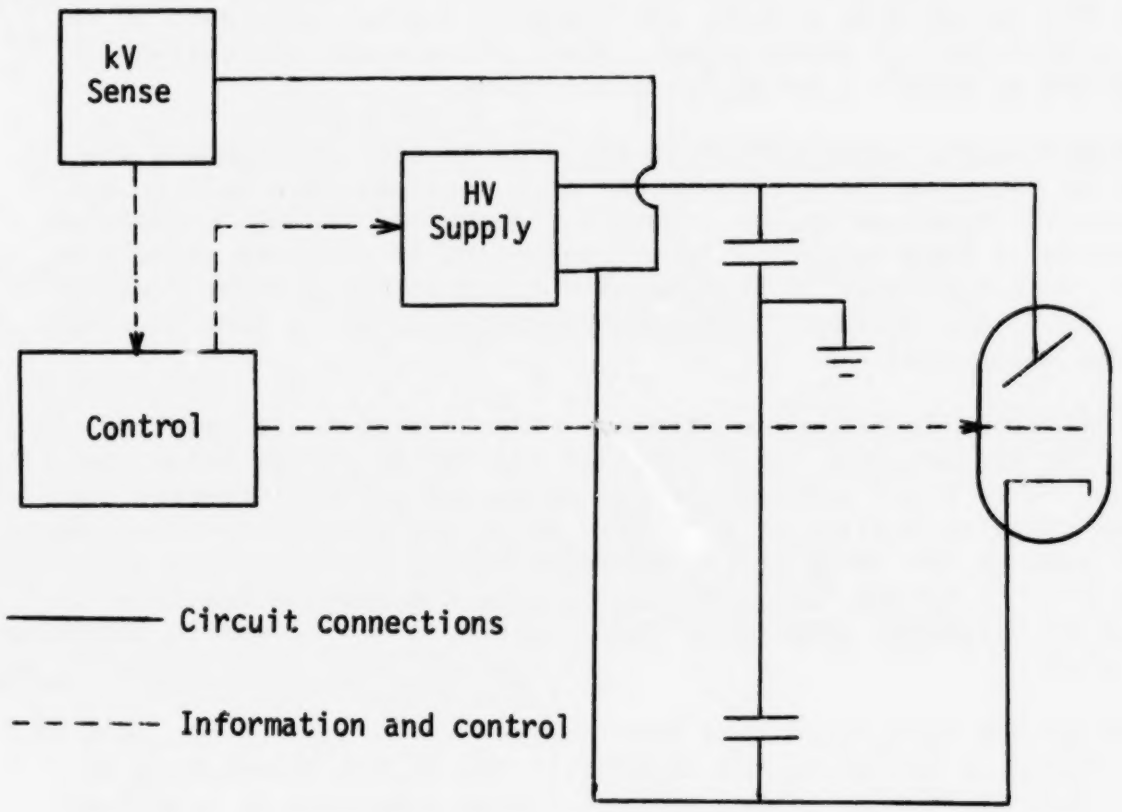

Figure 3. Block diagram of circuit for Westinghouse machine.

3. MEASUREMENTS AND TESTS

3.1 VOLTAGE MEASUREMENTS

The anode and cathode voltages were measured with a voltage divider. The magnitudes of these voltages were found to be the same within 1 percent. The cathode voltages were measured at various settings and multiplied by 2 to determine the total tube voltage.

Figure 4 is a graph of total tube voltage versus the meter indication. The meter reading was about 1/2 kV low at all voltages. In this report kV values given are those indicated on the meter unless otherwise specified.

A 30-second warmup period is recommended in the instruction manual. Before the end of this period, the charging voltage was found to be about 2 kV below its final value. After 30 seconds, the voltage stabilized to within 1 kV of its final value.

Simultaneous measurements of the drop in tube voltage and the mAs of an exposure (described in the next section) were made to determine the capacitor values. Both the anode and cathode capacitors were found to have values of 2.0μF, resulting in a series value of 1.0μF. Each capacitor is shunted with a 250-megohm bleeder resistor which causes its voltage to decay exponentially with a time constant of about 8 minutes.

The automatic charge-maintenance circuit accurately restored the voltage to the original value after it had fallen 1.7 kV below the maximum. The "high" position of the technique switch increased the initial charging voltage by 10.5 kV. The times required for charging were 6 seconds for 70 kV and 14 seconds for 100 kV. When the power switch was set to the "discharge" position, the machine required 75 seconds to discharge completely from 100 kV and 45 seconds to discharge from 70 kV.

After the capacitors have been charged for a short time, some of their charge is stored in the dielectric and is not immediately released upon discharge. This residual charge reappears as a voltage on the capacitors a few minutes after discharge. The voltage from this source may be as high as 200 volts. The possibility of shock from this residual charge is not mentioned in the instruction manual

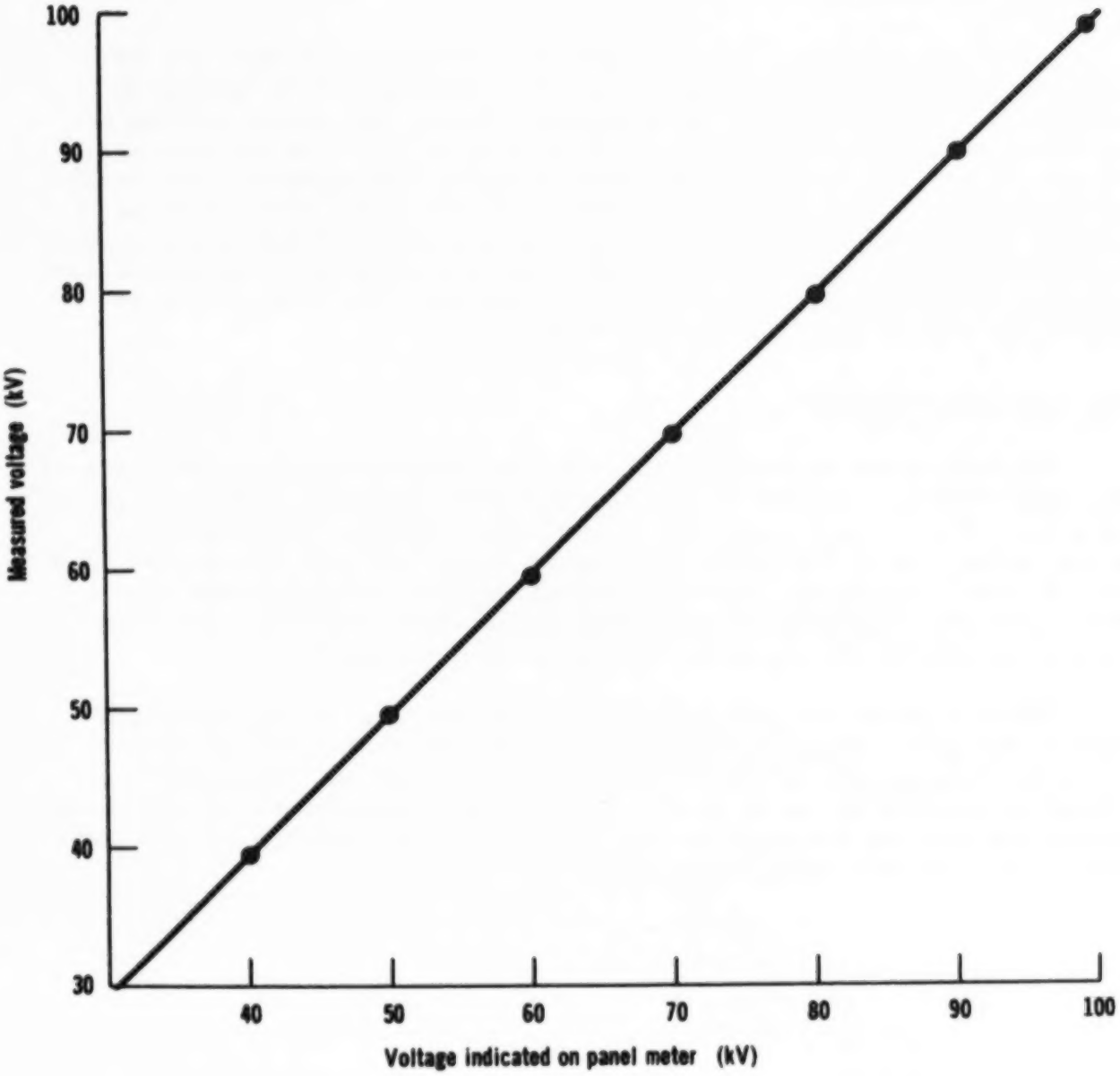

Figure 4. Measured versus indicated tube voltage for Westinghouse machine.

provided with the unit. This hazard can be minimized by taking the following steps before removing the high-voltage cables after the machine has been in use. (1) Discharge the capacitors through the tube by using the "discharge" position of the power switch. (2) Depress the mechanical discharge plungers. (3) After a 3-minute delay to allow the capacitors to "relax", operate the plungers again before removing the cables.

After the unit has been charged to a selected voltage, the kV selector should not be changed to a lower setting before making an exposure. This precaution is necessary because the final voltage of an exposure is determined by the kV setting at the time of exposure. If the kV setting is lowered between charging and exposure, the final voltage of the exposure will be reduced to the level that would be correct at the new setting, causing a larger value of mAs and a greater exposure than was intended. In addition, the filament temperature increases in steps as the kV setting is lowered. The combination of higher kV and mA could damage the tube.

3.2 mAs MEASUREMENTS

To facilitate measurement of the tube current, the ground leads of the high-voltage capacitors are accessible outside the high-voltage enclosure. These leads carry the actual tube current. A resistor of known value, about 100 ohms, was placed in series with the ground lead of the anode capacitor. An integrating digital voltmeter was used to determine the volt-seconds appearing across this resistor, and from this measurement the exposure mAs could be determined.

Table 1 gives the mAs values as a function of kV and technique switch setting. Changing the technique switch from "low" to "high" without changing the kV control decreased the mAs and increased the charging voltage by about 10 kV. Hence, each measurement at the "high" technique setting was made at the same kV control setting as the "low" technique exposure immediately above it.

Table 1. Measured mAs for various exposure settings.

kV meter reading	Technique switch setting	mAs per exposure
30 kV	low	8.5
40 kV	high	7.9
45 kV	low	13.6
55 kV	high	10.5
60 kV	low	17.9
70 kV	high	11.6
75 kV	low	22.4
85 kV	high	13.2
90 kV	low	25.5
100 kV	high	14.6
100 kV	low	26.9

3.3 LINE VOLTAGE AND CURRENT

To compensate for differences in line voltage, a voltage stabilizing transformer is used in the power supply. The machine, as supplied, was wired for operation from a 120-volt line. According to the instruction manual, the unit should operate properly between 102 and 132 volts when wired for 120 volts. It was tested over this range, and no significant changes in kV or mAs were observed. However, a 5 percent change in filament voltage was observed. This would cause a significant change in instantaneous mA, although the total output would not be affected. If the unit is normally operated at a voltage near the limit of its compensating range, the line-voltage tap should be moved to a tap closer to the actual value.

With the line voltage at 122 volts, the line current was measured during charging. The peak current was 16 amperes at the beginning of charging from zero. The current decreased to 10 amperes in 3 seconds and to 5 amperes in 10 seconds. The idle current was less than 1 ampere.

3.4 EXPOSURE REPRODUCIBILITY

Exposure reproducibility was checked on the "low" setting at 40, 70, 90, and 100 kV and on the "high" setting at 50, 80, and 100 kV. Standard deviations were calculated from a sample of 10 exposures for each of the above techniques. In all but two cases, the standard deviation of exposure was less than 2 percent of the average value. At 40 kV ("low" setting) and 50 kV ("high" setting) the standard deviations of exposure were 2.1 and 3.1 percent respectively.

3.5 FOCAL SPOT SIZE AND LOCATION

The location of the focal spot was determined by inserting a lead diaphragm with two pinholes 1.4 cm apart into the beam. The distance between the two focal spot images on film was used to calculate the distance from the focal spot to the pinholes. The average of several determinations showed that the focal spot was 22.4 cm behind the collimator face plate. The tape measure mounted on one end of the tube housing to indicate distance from the focal spot was accurate to within 0.2 cm.

The focal spot size was determined according to the method recommended by the ICRU.[1] An image of the focal spot was produced by placing a diaphragm with a 0.075-mm-diameter pinhole between the focal spot and the film. Several images were made at various distance ratios, and the focal spot size, as defined by the ICRU, was found to be 2.3 by 1.8 mm. To account for the normally less-intense radiation from the ends of a line focal spot, the definition specifies that the effective length is 0.7 times the overall length. In the Westinghouse machine the radiation was uniformly distributed, and a more realistic estimate of the effective size, omitting the factor of 0.7, is 2.3 by 2.6 mm.

3.6 BEAM COLLIMATION AND LIGHT LOCALIZER

The relationship between the x-ray beam and the light localizer was determined by marking the edge of the lighted area with lead pieces on a sheet of film. The film was then exposed with the lead markers in place. The edge of the light field is defined as the point where the intensity of the light, determined with a narrow-field light meter, is

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[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL UNITS AND MEASUREMENTS. Report 10f 1962: Methods of evaluating radiological equipment and materials. National Bureau of Standards Handbook 89, p. 1 (1963).

one-fourth of its level at the center. The edge of the x-ray beam is the point where the exposure,determined from the film density, is one-tenth of its level at the center.

At a source-film distance of 1 meter, the collimator was set to give a field size of 8 inches by 10 inches according to its indicators. The light field was found to be 8-3/8 inches by 10 inches. The maximum error between the edges of the light and radiation fields was 0.5 cm.

3.7 INHERENT FILTRATION

The inherent filtration of the tube housing was determined by comparing the attenuation curves obtained from the Westinghouse machine with those obtained from a machine of known filtration and voltage.[2] The machine used for comparison had 1 mm of beryllium in the x-ray tube port and 1.5 mm beryllium and 0.25 mm aluminum added filtration, giving a total of about 0.3 mm aluminum equivalent filtration. Its power-supply filtering was such that the tube voltage peak was 98 kV and fell 4 kV between power-supply pulses. This variation between 94 and 98 kV is similar in effect to the variation in tube voltage in the Westinghouse machine during a 98-kV, 4-mAs exposure. A variable resistor was temporarily added to the timer circuit to allow such an exposure. Attenuation curves in aluminum were prepared at these measured operating conditions with identical geometry for the two machines. The curves extended to 5 mm aluminum for the Westinghouse machine and to 10 mm for the comparison machine. Radiation measurements for the Westinghouse curve were made with a Victoreen Integrating Ratemeter model 555 and a 1DA chamber. Radiation from the comparison machine was measured with a free-air ionization chamber.

One attenuation curve was prepared for the Westinghouse unit with only the tube housing window in the beam. This curve from 0 to 5 mm closely matched the comparison curve from 0.7 to 5.7 mm, indicating that the Westinghouse tubehead had approximately 0.7 mm more filtration than the 0.3 mm of the comparison machine; hence, the inherent filtration of the Westinghouse machine is about 1.0 mm. A similar comparison of curves indicated that the Westinghouse tubehead and collimator together had an inherent filtration of approximately 1.1 mm. The reason for the small filtration of the collimator is that the mirror, which holds the beam shutter, is removed from the beam during exposure. The

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[2] QUIMBY, E.H., L.S. TAYLOR, AND O. GLASSER ET AL. Physical Foundations of Radiology (3rd edition). Paul B. Hoeber, Inc., New York, pp.258-260 (1961).

machine was furnished with 1.74 mm of added filtration, and a total of 3.0 mm aluminum was found by comparison of attenuation curves with the filter added.

3.8 HALF-VALUE LAYER

Attenuation in aluminum was measured and the first and second half-value layers determined from the resulting attenuation curves. Radiation measurements were made with a Victoreen Integrating Ratemeter model 555 and a model 1DA ion chamber. Because energy dependence affects all measurements similarly, its effect on the attenuation curves was ignored. The chamber axis was parallel to the x-ray beam, and the center of the chamber was placed 100 cm from the focal spot. The attenuators and a lead sheet with a 1-inch hole were placed halfway between the focal spot and the center of the chamber. The lead sheet, placed next to the chamber side of the attenuators, limited the beam size to an area slightly larger than that of the chamber. Half-value layer measurements were not corrected to zero beam size as suggested by Trout,[3] because the maximum error from this cause is reported to be about 2 percent at 100 kV for the geometry used.

The first and second half-value layers in millimeters of aluminum and the homogeneity coefficients are given in table 2. The homogeneity coefficient is the ratio of the first and second half-value layers and gives an index of the energy distribution of the beam.

Table 2. Half-value layers and homogeneity coefficients.

Technique	1st HVL (mm Al)	2nd HVL (mm Al)	Homogeneity coefficient
40 kV, low	1.2	1.4	0.86
50 kV, high	1.7	2.0	0.85
70 kV, low	2.2	3.0	0.73
80 kV, high	2.7	3.8	0.71
90 kV, low	2.8	4.1	0.68
100 kV, high	3.7	5.2	0.71
100 kV, low	3.1	4.6	0.66

[3] TROUT, E.D., ET AL. Determination of half-value layer. Amer. J. Roentgen. 84:4:729 (1960).

3.9 RADIATION OUTPUT

Using the same arrangement employed for determining half-value layers, the radiation output for various exposures was determined. Figure 5 is a graph of radiation output versus starting voltage for high and low settings of the technique switch.

3.10 TUBE HOUSING LEAKAGE

With the beam port blocked with more than 10 half-value layers of lead as recommended by the NCRP,[4] the tube housing was wrapped in x-ray film. After 10 exposures of 100 kV at the "low" setting, the film was processed and examined for evidence of radiation leaks. The most intense leak was found to be at the junction between the tube housing body and face plate on the front. Measurements with a Victoreen 666 and the 4-inch chamber indicated, after energy dependence correction, that at 1 meter this leak emitted 0.11 mR per exposure at 100 kV, "low" setting.

With the filters and collimator in place and the collimator closed, the leakage was again checked. The most severe leakage still occurred in the tube housing area described above.

Tube-housing cooling curves were not furnished with the unit. By comparison with a similar housing, it was estimated that temperature limitations would allow 240 exposures per hour at 100 kV, "low" setting. This gives an exposure of 26 mR in 1 hour at 1 meter, which is within the limit of 100 mR in 1 hour recommended by the NCRP.[5]

3.11 SPURIOUS RADIATION

Because the full voltage is applied to the tube whenever the capacitors are charged, instead of only during exposure as in the case of conventional machines, capacitor discharge units have the capability of emitting x rays at times other than during an exposure. The Westinghouse machine emits spurious radiation in the two cases described below.

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[4] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Report No. 33: Medical x-ray and gamma ray protection for energies up to 10 MeV. NCRP, Washington, D.C., p.15 (1968).

[5] Ibid.

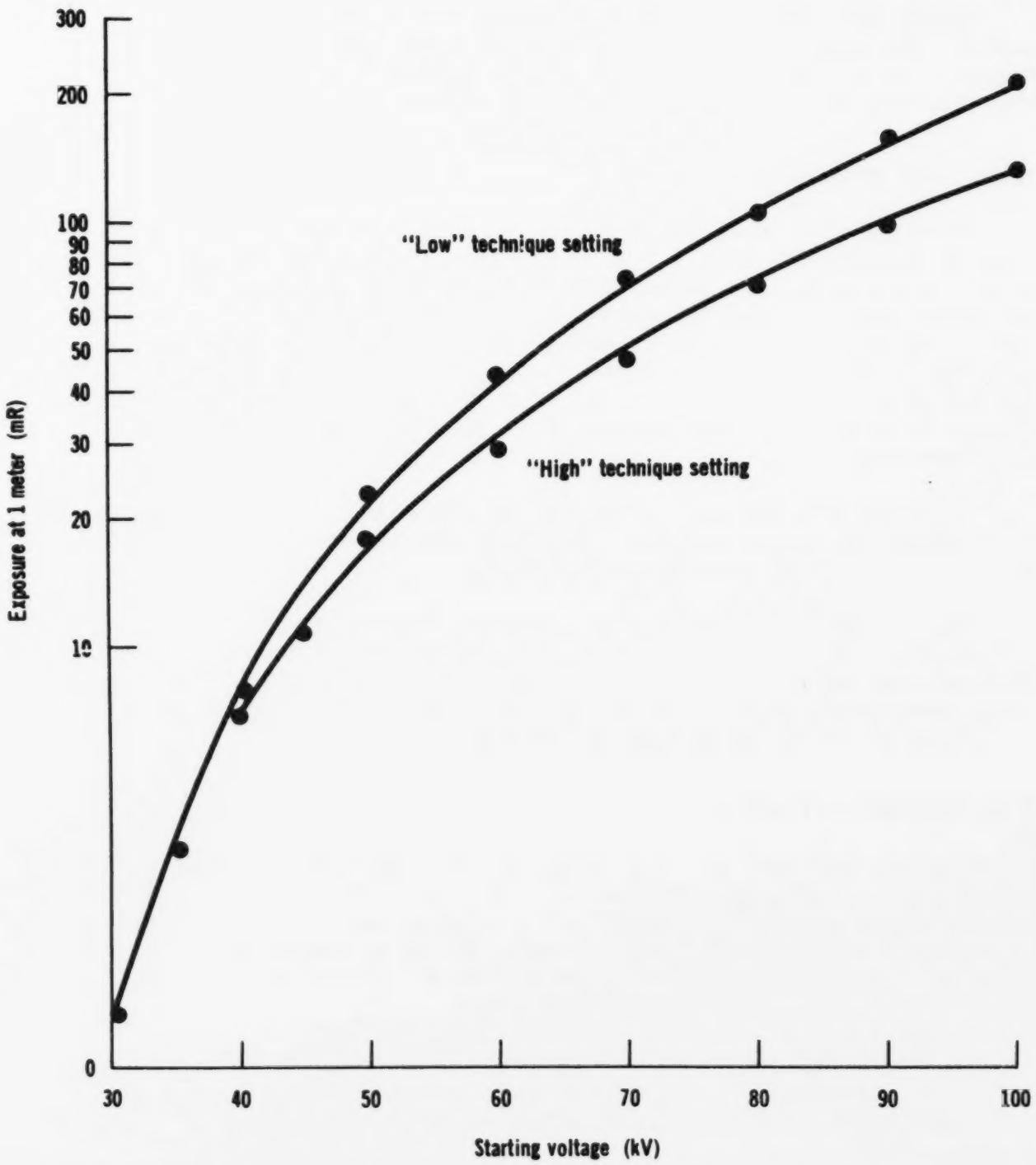

Figure 5. Output versus starting voltage for "high" and "low" technique switch settings.

In each case the radiation originates at the focal spot and passes out the beam port. In one situation leakage from the tube housing is also significant. Radiation is emitted by certain operations of the power switch and also as a result of field emission current whenever the capacitors are charged above approximately 80 kV. Except where noted, all measurements were made with a Victoreen 666 and the 4-inch chamber. Readings were increased 10 percent to correct for energy dependence.

(a) Power Switch Operation

Radiation emission can result from three different operations of the power switch. First, switching from "on" to "off" or "discharge" while the exposure button is in the first (preparation) position produces a 100-mR pulse at 1 meter and 100 kV, measured with the 1-1/4-inch chamber. The emission occurs because the filament is heated and the shutter removed from the beam when the exposure button is in its preparation position, and turning the power switch to either "off" or "discharge" removes the grid bias. This exposure is sufficient to expose film at normal distances and also poses a potential hazard to the operator. Even with the shutter disabled, no pulse is emitted unless the filament is heated to operating temperature because no voltage is applied to it in the standby mode. The shutdown procedure in the instruction manual does not indicate any restriction against switching the power switch to "discharge" or "off" until a few seconds after the exposure button has been released.

Second, the "discharge" position itself produces radiation. The function of this mode is to discharge the capacitors by allowing about 2 mA to flow through the tube while the beam shutter is closed. With the collimator open, the maximum leakage rate through the shutter, which occurs at about 95 kV, is 11 mR/hr at 1 meter, and the integrated exposure for the entire discharge operation from 100 kV is about 0.003 mR at 1 meter. Leakage from the tube housing was 17 mR/hr maximum and 0.08 mR integrated for the same conditions.

The shutter is operated by an a.c. motor with two windings, one to remove the shutter from the beam and the other to replace it. An interlock is provided to prevent exposure (but not charging) if the shutter is not fully retracted from the beam. There is no interlock to prevent a discharge operation if the shutter is open. If the motor fails completely, the only indication is inability to make an exposure. Following the recommended shutdown procedure

with the shutter open would result in a discharge operation. If only the winding which closes the shutter fails, no indication is given. When the shutter is not held closed by the motor, it swings freely and will be open if the beam is directed downward. If a discharge operation from 100 kV is carried out with the shutter open, the maximum exposure rate, measured with the 1-1/4-inch chamber, is 66 R/hr at 1 meter, with an integrated exposure of 380 mR. Such failures are unlikely but not impossible.

Third, if the power switch is turned from "discharge" to "off" before the discharge is complete, a pulse of radiation is emitted. This occurs because the filament is heated to a low temperature during discharge, and the shutter is no longer held in the beam when the machine is off. This pulse is 0.05 mR at 1 meter and 90 kV, and 0.02 mR at 1 meter and 60 kV.

(b) Field Emission (Dark Current) Radiation

Whenever the capacitors are charged to a sufficient voltage, a small current flows in the tube. This occurs because the electric field strength at the grid is sufficient to cause electrons to be pulled from its surface and strike the anode. This small current is not affected by either the grid bias or the filament temperature. At 100 kV this field emission current produces observed exposure rates of 1 to 10 mR/hr at 1 meter with the shutter removed from the beam. The exposure rate is variable, depending on tube temperature and history of operation. As the tube voltage falls, the radiation intensity falls and is less than 1 percent of maximum at 80 kV. The voltage normally falls from 100 to 80 kV in 2 minutes, and the integrated exposures observed were between 0.004 and 0.04 mR at 1 meter. With the shutter in the beam, as it normally is except immediately prior to exposure, no radiation could be detected. Since this radiation is not emitted except immediately before exposure, the amount is negligible. Because of the extreme variability of exposure, it is not known whether these observed exposures represent absolute limits. In addition, individual tubes may differ significantly.

In addition to these observed cases of spurious radiation, failure of the x-ray tube grid bias would result in exposures with large and uncontrollable mAs values. This occurs because the tube conducts as soon as the filament is heated by pushing the exposure button to the preparation position, and current flow is not stopped after the correct mAs is reached. The resulting exposure discharges the capacitors to a

low voltage and overexposes the film and the patient. This condition cannot be detected until an exposure is attempted and the operator notices that the kV meter begins falling before the exposure button is operated. Such a failure did not occur during these tests, but the grid bias appears between two conductors of the cathode high-voltage cables and a breakdown is possible.

4. CONCLUSIONS AND RECOMMENDATIONS

As a result of this evaluation, the Division of Electronic Products has made certain suggestions to the manufacturer, CGR Medical Corporation (formerly Westinghouse Electric Medical Electronics Division), for improving the radiation safety of this machine. In response to these suggestions CGR Medical Corporation has agreed to make the following changes:

(1) A spacer to limit the minimum source-skin distance to 12 inches is being installed on new units. It is also available to users of earlier units without charge.

(2) To eliminate the possibility of field emission radiation in the event of failure of the shutter drive motor, a spring will be installed to hold the shutter closed except just before and during an exposure. At a later time, this spring will be replaced by an electrical interlock which will prevent charging or discharging the unit unless the shutter is held closed by its motor.

(3) A visual indicator of grid bias failure will be included in future units.

In addition to these modifications, the manufacturer will supply additional information on proper use of the machine. Addenda to the instruction manual will be furnished to all users, describing the symptoms of grid bias failure and procedures to be followed in the event of its occurrence and warning that the power switch should not be switched to "Discharge" or "Off" when the exposure button is pressed or within 2 seconds after it is released.

APPENDIX A

SPECIFICATIONS FOR WESTINGHOUSE CAPACITOR DISCHARGE MOBILE X-RAY MACHINE

Manufacturer	:	CGR Medical Corporation (formerly Westinghouse Electric Corp. Medical Electronics Division) and Shimadzu Seisakusho, Ltd.
Tube Voltage	:	30 to 100 kV
Capacitance	:	1μF
Power Requirement:		90, 100, 110, 120, 200, 220, 230, 250, and 260 volts, 50 or 60 Hz, 1 kvA, less than 1 ohm impedance

DIVISION OF ELECTRONIC PRODUCTS

Technical Reports

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	Title
BRH/DEP 70-18	Bremsstrahlung Production (July 1970) (NTIS, PB 192 888, $3.00)
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BRH/DEP 71-3	Evaluation of the Picker Capacitor Discharge Mobile X-ray Machine (February 1971) (NTIS, PB 198 080, $3.00)
BRH/DEP 71-4	A Radiation Survey of Television Repair Shops in the Baltimore Area (March 1971) (NTIS, PB 198 240) (GPO, $0.50)
BRH/DEP 71-5	Electromagnetic Radiation Interference with Cardiac Pacemakers (April 1971) (GPO, $0.45)
BRH/DEP 71-6	Evaluation of Lithium Fluoride for Microwave Dosimetry Applications (April 1971)
BRH/DEP 71-7	Construction and Evaluation of a Kit-Form Microwave Oven (May 1971)
BRH/DEP 71-8	Evaluation of the Westinghouse Capacitor Discharge Mobile X-ray Machine (May 1971)